Revegetation
Supplement 2.30

Statistical Examples
To Be Used When Analyzing Data
For Seed Germination and Seedling Growth Activities

Example 1

The following data represents the number of germinating seed from 25 seed of 4 species germinated in 5 petri dishes.

Petri Dish	blue grama	Mesquite	sideoats grama	alkali sacaton
1	15	10	25	09
2	14	08	23	07
3	15	07	24	09
4	13	11	25	10
5	14	09	21	09

Step 1. Add each of the 4 columns, and obtain 4 totals then add the 4 totals.

71 **45** **118** **44** The total is **278**.

Step 2. To determine the mean for each column or species, divide the column sum by 5, and add the 4 totals.

71/5 =	45/5 =	118/5 =	44/5 =	
14.2	**9.0**	**23.6**	**8.8**	The total is **55.6**.

Step 3. To determine the overall species mean divide 55.6 by the 4 species.

The total is **13.9.**

Step 4. Square each item in each column and add the products.

$15^2=225$	$10^2=100$	$25^2=625$	$09^2=081$	
$14^2=196$	$08^2=064$	$23^2=529$	$07^2=049$	
$15^2=225$	$07^2=049$	$24^2=576$	$09^2=081$	
$13^2=169$	$11^2=121$	$25^2=625$	$10^2=100$	
$14^2=196$	$09^2=081$	$21^2=441$	$09^2=081$	
1,011	**415**	**2,796**	**392**	The total is **4,614**.

Step 5. Square the answer in **Step 1**, and divide by 5, which is the number of observations.

$(71)^2/5=$	$(45)^2/5=$	$(118)^2/5=$	$(44)^2/5=$	
1008.2	**405.0**	**2,784.8**	**387.2**	The total is **4,585.2**.

Step 6. The sum of the 4 columns in **Step 1** is 278. Square the number and divide by the total **df**, $(278)^2/20$ = **3,864.2.** Now subtract this number from the total in **Step 4**. The number is **749.8**.

Step 7. Now determine the differences between **Steps 4 and 5**, and add for a total.

2.8 **10.0** **11.2** **4.8** The total is **28.8**.

From the provided information it is possible to obtain three estimates of the population variance.

First **(A)**, we can determine the variance for the entire experiment. To do this we **use the product of Step 6 or 749.8** or **the Population Variance for the entire experiment**. Make sure you know where this number came from.

Second **(B)**, we can determine the variance for the four species. To do this we add the products in **Step 6** (2.8+10.0+11.2+4.8), this equals **28.8**. The total degrees of freedom (**df**) in this experiment is the number of petri dishes times the number of species (5 X 4) or 20. There are four species and 1 **df** is lost for each species, so there are 20-4 or **16 df**. Now divide 28.8/16. This equals **1.8 or the Population Variance for the four species**.

Third **(C)**, we can determine the variance or the species means or species totals. To do this we square the product of each column in **Step 1** and divide by the total items for each group (5). That number is subtracted from the square of the total product of **Step 1** (278) divided by the total **df** in the experiment (20), or

$$\frac{(71)^2+(45)^2+(118)^2+(44)^2}{5} - \frac{(278)^2}{20}$$

$$\frac{(5{,}041)+2{,}025)+(13{,}924)+(1{,}936)}{5} - \frac{(77{,}282)}{20}$$

4,585.2 - 3,864.2 This equals **721**.

Now we can create an **Error Table** and determine if there are differences among species.

Source of Variation	df	Sum of Squares	Mean Square	F Ration
Total	19	749.8	039.46	
Between Species	03	721.0	240.33	
Within	16	028.8	001.80	133.52

Let's make sure you know where all the numbers in the table come from:

(**1**) Under **df**, there a total of 20 **df**, or 5 petri dishes times 4 species. To determine the Total **df** subtract 1 from 20, the answer is 19. To determine the Between Species **df** remember there are 4 species, so subtract 4 -1, the answer is 3. To obtain the Within **df** subtract 19 - 3, the answer is 16.

(**2**) Under Sum of Squares, the 749.8 is from **Step 6** where the total of the four columns in **Step 1** is totaled and squared and then divided by the experimental total **df** which is 20. This number is subtracted from total in **Step 4, or 4,614-3,864.2**; this equals **749.8.** To obtain the Mean Square divide 749.8 by the 19 **df**. The **Mean Square for the Total is 39.46**.

(**3**) Under the Sum of Squares, the 721 is from **C**. Each column in **Step 1** was squared and then the four columns added. The product of the four columns was divided by 5, the total number of petri dishes. This total number was subtracted from the total of the 4 columns in **Step 1**, and the total squared, the **Sum of Squares for the Between species is 721**. Now divide the Sum of Squares by the Between species **df** or 721/3, the **Mean Square for the Between species is 240.33**.

(**4**) The Within **df** and Sum of Squares, are calculated by subtracting the Totals from the Between Species; therefore, 19 – 3 = 16, and 749.8 - 721.0 = 28.8. To obtain the Within Mean Square divide 28.8 by 16 **df**, the **Mean Square for the Within is 1.80**.

(**5**) To obtain the **F Ratio**, divide the Mean Square Between species by the Mean Square Within. The **F Ratio is 240.33/1.80, or 133.52**.

(**6**) Now go to the provided **F table.** Follow the rows down to 16 (Within), and the columns across to 3 (Between species); the number at row 16 and column 3 at the 0.05 probability level is 3.24. Compare this with our computed **F Ratio of 133.52**. If the calculated **F Ratio is greater than the F Table value, there is a significant difference between species.**

Activities

1. Students collect soils, thoroughly mix soils and screen soils to remove rock and debris. Students determine the effects of soil planting depths, soil texture, and clay fractions within similar soil textural classes on emergence of selected native Chihuahuan Desert plants.

2. Students collect soils with textural characteristics common to the area where the restoration project will be done.

3. Students screen each soil type to 5mm, thoroughly mix, and store in separate bins or barrels. Students add soil to 150 X 150mm tapered plastic pots at 127, 122, 117, 112 and 107mm depths above the pot base. Students sow 25 pure live seed on one genotype on the media surface of each pot. Students add soil to 127mm depths in all pots. Thus, seed are planted at 0, 5, 15 and 20mm depths.

4. Students place pots in 0.15 X 1.50 X 2.25m sheet-metal pans, and subirrigate in distilled water. Subirrigation is used to ensure that soil surfaces are moist and

undisturbed during the 14-day study. Emergence is considered complete when the first leaf is15mm above the soil surface in those pots where seed are planted at 5 to 20mm depths, or when the first leaf is 15mm above the soil surface and the radical has penetrated the soil in those pots in which seed were sown on the soil surface. Seedling counts are made daily.

5. Each student group fills pots, plants seed and records data for seed planted at the five depths. If classroom temperature varies from 25 to $30^{0,}$ this experiment can be placed by a window where seedlings should receive three to five hours of direct light. This approach ensures student understanding of the replication process. Students measure variability within species for each depth with the collected data sets using statistical techniques.

REMEMBER: One pot will be used for one species or genotype of a species, and seed in one pot will be planted at one depth. Total seedling emergence will be determined by accumulating the number of emerging seedlings for each pot over the 14-day period, and seedling emergence for the respective species or genotype will be compared with **analysis of variance at days 6 and 14**.

Example 2

The following data represents the number of emerging grass and shrub seed from 25 seed of four species planted at the ***same depth*** (0.5cm). The data from each numbered plastic pot would come from a different student group. In this case there were 30 students in the class and five students in six groups.

Plastic Pots	Blue grama	Sideoats grama	Mesquite	Whitethorn acacia
1	10	21	15	22
2	11	19	13	25
3	09	21	16	22
4	11	20	15	21
5	08	15	10	18
6	11	22	16	22

Look at the data from plastic pot 5. The individual data points are lower than the remaining five pots. Take the time to identify this data set and illustrate that it is lower than the others. Identify the group with the low numbers and congratulate them on providing the group “real numbers”. In other words don’t give in and change numbers to fit with the other five groups. There are times when the data collected do not follow the established or expected trend. When this occurs, it is the responsibility of the scientist or scientists to think and come up with a reasonable explanation. Some reasonable explanations may be: (1) seed were planted deeper than reported, (2) temperatures in the classroom where the pot was placed were either cooler or hotter than reported and (3) the variability in the seed used in this portion of the study did not germinate as well as those seed selected for the other five pots. **REMEMBER:** Our objective is to logically think and critically evaluate the collected data.

Example 3

The following data represents the total number of all grass and shrub emerging seedlings from three soil types at the ***same depth*** (0.5cm). The data from each numbered plastic pot would come from a different student group. In this case there were 30 students in the class and five students in six groups.

Plastic Pots	Soil Type: Sand	Soil Type: Silt	Soil Type: Clay
1	40	36	25
2	45	41	21
3	43	33	19
4	41	32	22
5	40	31	23
6	39	36	21

Please note that when the columns are added there are fewer seedlings in the clay soil. In high rainfall areas like the upper Midwestern United States, annual rainfall averages 550 to 1,000mm. In contrast, in the Chihuahuan Desert annual rainfall averages 200 to 400mm. When rainfall exceeds 550mm clay soils are ideal for growing plants, but in the Chihuahuan Desert clay soils are the worst for growing plants. Where plant growth is great roots penetrate the soil and water infiltration is great. Nevertheless, clay particles hold water, and water tightly held by clay particles is unavailable to plants. In wet areas water in the soil is so abundant that water held by clay particles is of little consequence. But in deserts, there is less plant growth, the heat seals surface soils and this combined with water tightly held by clay particles means less plant matter will be produced on clay soils. Just the opposite is the case in sandy soils. In sandy soils water enters quickly because particles are larger. Water is not held by the sand particles and there is greater plant growth on sandy soils.

Have students conduct an analysis of variance on the data in Examples 2 and 3. In Example 2, use the same format as in Example 1, but note that in Example 2 there are six replications rather than five. Example 3 requires six replications, but they are of three soil types rather than four plant species. Keep these factors in mind when doing the analysis of variance.